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BATSE OBSERVATIONS OF 3C273

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ABSTRACT

The quasar 3C273 has been detected by all instruments on CGRO. The emission from this source is monitored continuously by BATSE using Earth occultation. We present results of a preliminary analysis of BATSE data, including light curves of the 3C273 flux covering ~150 days in the interval April–August 1991 and ~350 days in the interval July 1992–April 1993. The source intensity in the energy range 50–300 keV is typically ~0.002 ph cm^{-2} s^{-1}. We find weak evidence for variations of as much as a factor of 3 in the intensity. We derive spectral parameters of 3C273 during the intervals TJD 8422–8435 (15–28 June 1991) and TJD 8532–8546 (3–17 October 1991) for comparison with other CGRO instruments.

1. INTRODUCTION

3C273 is the nearest quasar ($z = 0.16$) and is one of the best-studied extragalactic objects. It is detectable over most of the electromagnetic spectrum (see Courvoisier et al. 1990 for a review), and, prior to the launch of CGRO, it was the only quasar detected in gamma-rays. The first pointed CGRO observation of 3C273 (15–28 June 1991) occurred as part of an international campaign to obtain a simultaneous wideband spectrum of this source (Lichti et al. 1994).

The wide-band spectra of quasars (and AGNs in general) differ significantly from those of stars and most other astrophysical objects. Roughly speaking, the energy flux density (νF_ν) spectrum emitted from quasars is remarkably flat over a wide range, often the entire range from radio to gamma-rays. It is clear, however, that the entire spectrum cannot be explained by a single process. The overall spectrum is a complex combination of many, time-varying, components, some of which are interdependent. For example, the ultraviolet emission in some AGNs may be due to reprocessing of the X-ray flux by the surface layers of the accretion disk (Clavel et al. 1992). Obviously, multi-wavelength study of temporal variability over long timescales is essential to understanding these sources. With its unusual monitoring capabilities, BATSE can contribute much to the study of AGNs by allowing long-term correlation studies between hard X-rays and other wavelengths.

2. OBSERVATIONS

BATSE is capable of nearly continuous monitoring of low-energy gamma-ray sources using Earth occultations (Harmon et al. 1992). Paciesas et al. (1993) reported initial results of observations of 3C273 using this technique. The occultation technique is continually being improved by the BATSE team, leading to improved statistical sensitivity and/or better understanding of systematic errors. We have also developed a technique for image reconstruction using the occultation data (Zhang et al. 1993, 1994). The observations of 3C273 reported here are the results of processing of nearly 450 days of BATSE occultation data using improved algorithms.

The data type used in this investigation consists of 16 energy channels covering the approximate energy range 20–2000 keVwith ~2 s time resolution. BATSE large area detectors facing within 60° of 3C273 were included; each usable occultation rise or set was fit separately

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for each detector and each energy channel using the energy-dependent atmospheric transmission profile of a constant source superimposed on a quadratically varying background. Data within approximately 2 minutes on either side of the occultation were used. Terms for additional sources were included if their occultations occurred during the fit interval and they were known from previous observations to be potentially bright. Occultation steps of 3C273 which occurred within 10 s of a step due to a potentially bright source were eliminated from the analysis.

To derive a long-term light curve, we averaged the count rate spectra from individual steps over each CGRO viewing period (~3–14 days), and deconvolved each average spectrum using conventional forward-folding techniques, assuming a power-law model spectrum with the photon index fixed at −1.7. The fit energy range was 50–300 keV. For technical reasons, we have thus far processed only about 400 days of data in two separate intervals: 144 days near the beginning of the mission (TJD 8368–8511) and 291 days more recently (TJD 8820–9110). We are continuing to process more of the data and will report the results of a longer-term investigation in a future publication.

It can be seen from Figure 1 that BATSE typically detects 3C273 at the 2–3σ significance level in a single two-week CGRO observing period. In some intervals, such as TJD 8960–9000, the fluctuations appear to be larger than expected from statistics alone. Without further study, we cannot rule out systematic effects as being responsible for this behavior; hence, use of these data to study fluctuations on timescales of less than about one month would be premature.

No clear long-term trend is evident in comparing the 1991 data with the 1992/1993 data. The typical source intensity over the entire interval studied is ~0.002 ph cm^{-2} s^{-1}, consistent with the level observed by OSSE (N. Johnson, priv. comm.) in the same energy range during viewing period 3 in June 1991 (TJD 8422–8435). We note that the single BATSE point which covers the latter interval is high relative to the average of the previous BATSE points as well as to the more precise OSSE measurement. This suggests that the high BATSE point may be a statistical fluctuation, but a systematic error of this size cannot be ruled out.

It is also noteworthy that the intensity during the interval TJD 8440–8500 is consistently lower than at other times. We know of no other 3C273 observations during this time to compare with; however, an OSSE measurement during CGRO viewing period 11 in October showed a flux approximately a factor of three lower than the June data (N. Johnson, priv. comm.). The data in Figure 1 suggest that this state of low flux began soon after the June measurements, and persisted at least several months.

To investigate this further, we processed additional data from viewing period 11 to allow a detailed spectral comparison with viewing period 3. We analyzed both data sets using the standard model-dependent forward-folding technique with a power-law model spectrum, allowing both the normalization and spectral index to vary. We found that the spectrum during viewing period 3 (TJD 8422–8435) was adequately fit by a power-law $dN/dE = A_{100}(E/100\,\mathrm{keV})^{\alpha}$, where $A_{100} = (1.8 \pm 0.4) \times 10^{-5}$ ph cm^{-2} s^{-1} keV^{-1} and $\alpha = -1.57 \pm 0.24$ ($\chi^2 = 37.6$ for 40 d.o.f.), whereas for viewing period 11 (TJD 8532–8546) we found $A_{100} = (7.3 \pm 3.6) \times 10^{-6}$ ph cm^{-2} s^{-1} keV^{-1} and $\alpha = -1.40 \pm 0.47$ ($\chi^2 = 42.9$ for 40 d.o.f.). These results provide weak support for the flux decrease between June and October, the latter being a factor of 2.5 ± 1.3 weaker at 100 keV. In both cases, the derived spectral index is consistent with the contemporaneous best-fit OSSE spectrum (N. Johnson, priv. comm.) but the integrated intensity is 50–100% higher. Since the significance of these differences is $\lesssim 1.5\sigma$, it is possible that both represent upward statistical fluctuations. Thus, we cannot be conclusive about systematic errors at this level in our data.

Recently, a technique for producing images using the BATSE occultation data has been

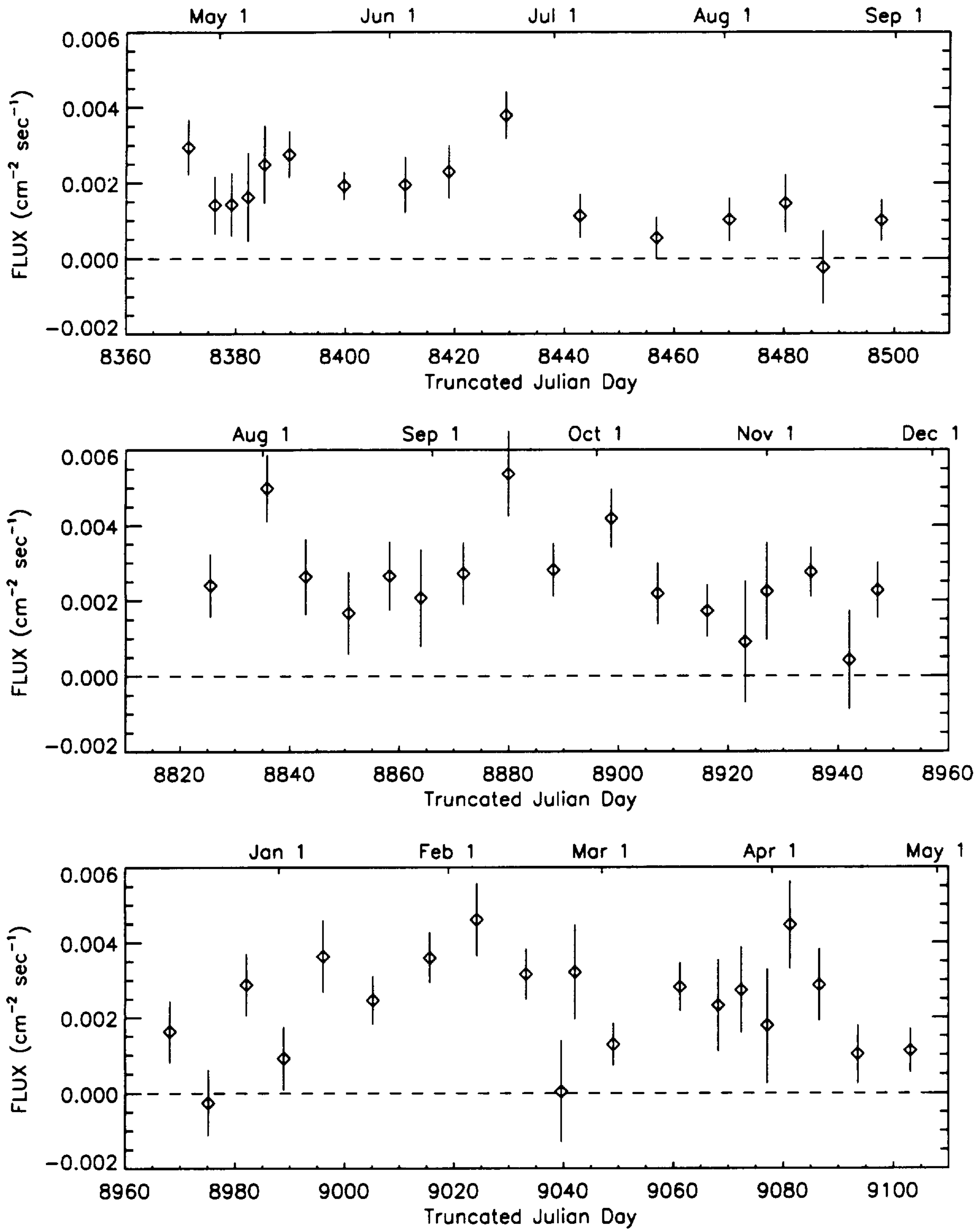

Figure 1: Long-term light curve of 3C273 as monitored by BATSE. The uppermost panel covers the interval from late April to late August 1991. The lower two panels span the interval from mid-June 1992 to late April 1993. Integrations correspond in time to CGRO viewing periods (~3–15 days). The energy range is 50–300 keV.

developed (Zhang et al. 1993, 1994). The technique uses a Radon transform applied to differentiated data (rate as a function of orientation angle and distance to the center of the field-of-view). Images are produced by inversion of the Radon-space data using one of several possible methods (least-squares fitting, maximum entropy method, or algebraic reconstruction). In order to verify that the emission we observed was associated with 3C273, we produced an image of a sky region containing 3C273, shown in Figure 2. It is clear that in this energy range (100–300 keV), only one source, consistent with 3C273, is visible in our data. With our limited angular resolution we cannot rule out the presence of emission from the source GRS 1227+0029 which is 15′ from 3C273 (Bassani et al. 1991); however, this source had a much steeper spectrum than 3C273 and would be unlikely to contribute much above ~50 keV.

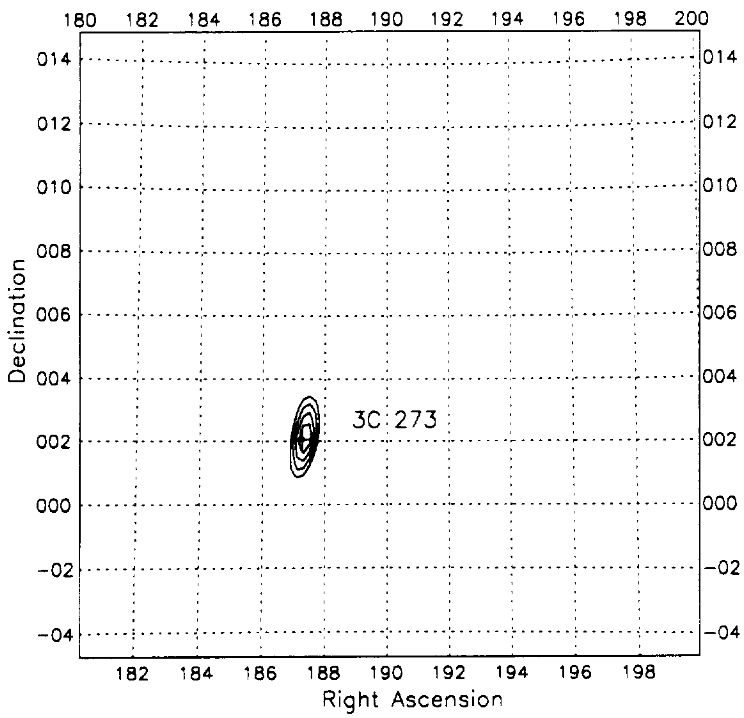

Figure 2: Image of the region near 3C273 during CGRO viewing period 3 (TJD 8422–8435) produced using the Radon transform and maximum-entropy inversion. The energy interval is 100–300 keV. The methodology is described in more detail by Zhang et al. (1993, 1994).

3. SUMMARY

Although the intensity of 3C273 is near our sensitivity limit, it is clear that BATSE can monitor long-term variability of the source. Using our current analysis techniques, the minimum timescale for reliable detection of source variability is about 1–2 months. We continue to investigate the occultation monitoring technique with the goal of improving the statistical precision of the method while controlling systematic errors.

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